

We claim:

1. An interconnect structure formed on a substrate, the structure comprising:
  - a dielectric layer overlying the substrate;
  - a hardmask layer on said dielectric layer, said hardmask layer having a top surface;
  - at least one conductor embedded in said dielectric layer and having a surface coplanar with the top surface of said hardmask layer;
  - a first cap layer on said at least one conductor and on said hardmask layer; and
  - at least one second cap layer on said first cap layer.
2. The interconnect structure according to Claim 1, wherein said first cap layer is formed by a high density plasma chemical vapor deposition (HDP CVD) process.
3. The interconnect structure according to Claim 1, wherein said second cap layer is formed by a plasma-enhanced chemical vapor deposition (PE CVD) process.
4. The interconnect structure according to Claim 1, further comprising a conductive liner disposed between said conductor and said dielectric layer.
5. The interconnect structure according to Claim 1, further comprising an adhesion promoter layer disposed between said dielectric layer and the substrate.
6. The interconnect structure according to Claim 1, wherein said dielectric layer is formed of an organic thermoset polymer having a dielectric constant of about 1.8 to about 3.5.

7. The interconnect structure according to Claim 6, wherein said dielectric layer is formed of a polyarylene ether polymer.
8. The interconnect structure according to Claim 1, wherein said first cap layer is formed of a dielectric material selected from the group consisting of silicon nitride, silicon carbide and boron nitride.
9. The interconnect structure according to Claim 1, wherein said first cap layer is formed of silicon nitride having a composition of about 40 atomic % silicon, about 52 atomic % nitrogen, and about 8 atomic % hydrogen.
10. The interconnect structure according to Claim 1, wherein said second cap layer is formed of a dielectric material selected from the group consisting of silicon nitride, silicon carbide and boron nitride.
11. The interconnect structure according to Claim 1, wherein said second cap layer is formed of silicon nitride having a composition of about 37 atomic % silicon, about 48 atomic % nitrogen, and about 15 atomic % hydrogen.
12. The interconnect structure according to Claim 1, wherein said second cap layer is formed of silicon carbide having a composition of about 27 atomic % silicon, about 36 atomic % carbon, and about 37 atomic % hydrogen.
13. The interconnect structure according to Claim 1, wherein said second cap layer is formed of amorphous hydrogenated nitrogenated silicon carbide having a composition of about 22 to 30 atomic % silicon, about 15 to 30 atomic % carbon, about 10 to 22 atomic % nitrogen and about 30 to 45 atomic % hydrogen.

14. The interconnect structure according to Claim 1, wherein said conductive material is copper.
15. The interconnect structure according to Claim 1, wherein said second cap layer comprises a plurality of thin films each formed by a plasma-enhanced chemical vapor deposition (PE CVD) process.
16. The interconnect structure according to Claim 15, wherein the plurality of thin films comprises at least one silicon nitride film and at least one film selected from the group consisting of silicon oxide, silicon carbide, boron nitride, silicon oxycarbide and silicon oxycarbonitride.
17. The interconnect structure according to Claim 1, wherein said first cap layer has a thickness of about 25 to 700 Å.
18. The interconnect structure according to Claim 1, wherein said second cap layer has a thickness of about 100 to 1000 Å.
19. The interconnect structure according to Claim 15, wherein each thin film has a thickness of about 50 Å.
20. A method for forming an interconnect structure on a substrate, the method comprising the steps of:
  - depositing a dielectric material on the substrate, thereby forming a dielectric layer,
  - depositing a hardmask material on said dielectric layer, thereby forming a hardmask layer, said hardmask layer having a top surface;
  - forming at least one opening in said dielectric layer;

filling said opening with a conductive material, thereby forming at least one conductor, said conductor having a surface coplanar with the top surface of said dielectric layer;

depositing a first material on said conductor, thereby forming a first cap layer; and

depositing a second material on said first cap layer, thereby forming a second cap layer.

22. The method according to Claim 20, wherein said second material is deposited by a plasma-enhanced chemical vapor deposition (PE CVD) process.
21. The method according to Claim 20, wherein said first material is deposited by a high density plasma chemical vapor deposition (HDP CVD) process.
23. The method according to Claim 21, wherein said first material is silicon nitride, and said HDP CVD process includes placing the substrate into a reactor chamber at a pressure of about 0.1 milli-torr to about 50 milli-torr and at a temperature of about 200°C to about 500°C, and exposing the substrate to at least one gas selected from the group consisting of silane, nitrogen, argon and helium.
24. The method according to Claim 22, wherein said second material is silicon nitride, and said PE CVD process includes placing the substrate into a reactor chamber at a pressure of about 0.1 torr to about 10 torr and a temperature of about 150°C to about 500°C, and exposing the substrate to at least one gas selected from the group consisting silane, ammonia, nitrogen and helium.
25. The method according to Claim 20, wherein said first material is deposited by a HDP CVD process under vacuum and said second material is deposited by a

PE CVD process under vacuum, without exposing the substrate to atmospheric pressure prior to deposition of said second material.

26. The method according to Claim 20, further comprising, after formation of said conductor and prior to deposition of said first material, the step of:  
performing a plasma pre-cleaning process which includes heating the substrate to a temperature of about 150°C to about 500°C and exposing the substrate to a source of hydrogen for a time of about 5 to about 500 seconds.